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Tidal variability of ice dynamics in the grounding zone of the Priestley Glacier, Antarctica, based on observation and modeling

Christian Wild (1), Oliver Marsh (2), Reinhard Drews (3), and Wolfgang Rack (1)

(1) University of Canterbury, College of Science, Gateway Antarctica, Christchurch, New Zealand (christian.wild@pg.canterbury.ac.nz), (2) British Antarctic Survey, United Kingdom, (3) University of Thuebingen, Germany

Tidal variations in the flow-speed of glaciers regulate the rate of Antarctica's ice discharge into the ocean. The mechanism behind the tidal modulation of ice discharge across the grounding line, however, remains poorly understood. It has been proposed that the magnitude and extent of observed velocity change is caused by tides lifting the glaciers off the bed, changing basal properties by 'pumping' ocean water far upstream of the grounding line and softening the basal till. Observations of changing basal properties to support this theory, however, are entirely lacking. Here we propose an additional, more microscopic process that is associated with large-scale velocity changes: With flexural stresses in the glaciers' grounding zone as well as mechanical weakening of ice in shear margins, ice crystals align in their preferred orientation to facilitate the ice flow. This results in a significant reduction of viscosity along lateral shear margins, with the potential to reduce ice-shelf buttressing on very short time scales. The lack of consensus on the mechanism behind short-term velocity change means that tidal variability is not yet parameterized in Antarctic-wide ice sheet models, directly affecting the reliability of predictions of future ice loss. In November 2018, we therefore deployed a high-precision radar system (TRI) on the Priestley Glacier, Antarctica, where adjacent rock outcrops provide the rare opportunity to install the TRI at fixed anchor points. This imaging radar system measures ice dynamics at both high temporal resolution and over the entire grounding-zone area with millimetre precision. Simultaneously, an array of glacier stations across the grounding zone record vertical and horizontal movement of the ice (GPS), changes in surface slope from tidal flexure (tiltmeters) and changes in basal properties from potential intrusion of ocean water upstream of the grounding line (ApRES). This in-situ data is complemented by satellite interferometry from TerraSAR-X, Sentinel 1a \& 1b and CosmoSkyMed plus an airborne ice thickness mapping campaign. We use this novel field data to constrain a state-of-the-art numerical model of tidal ice dynamics, to identify the mechanism behind short-term modulation of ice discharge. Although the Priestley Glacier is a small, little-studied glacier, it is representative of many outlet glaciers that drain Antarctica through the Transantarctic Mountains into the Ross Sea. If we are to better predict the rate of sea-level rise in an ongoing climate change, fully understanding of tidal modulation of ice dynamics is vital for estimating future ice loss with confidence.